


6-1950

# A Study of the Divide-Dewey Contact of the Boulder Batholith

Francis M. Young

Follow this and additional works at: [http://digitalcommons.mtech.edu/bach\\_theses](http://digitalcommons.mtech.edu/bach_theses)

 Part of the [Ceramic Materials Commons](#), [Environmental Engineering Commons](#), [Geology Commons](#), [Geophysics and Seismology Commons](#), [Metallurgy Commons](#), [Other Engineering Commons](#), and the [Other Materials Science and Engineering Commons](#)

---

## Recommended Citation

Young, Francis M., "A Study of the Divide-Dewey Contact of the Boulder Batholith" (1950). *Bachelors Theses and Reports, 1928 - 1970*. Paper 329.

This Bachelors Thesis is brought to you for free and open access by the Student Scholarship at Digital Commons @ Montana Tech. It has been accepted for inclusion in Bachelors Theses and Reports, 1928 - 1970 by an authorized administrator of Digital Commons @ Montana Tech. For more information, please contact [ccote@mtech.edu](mailto:ccote@mtech.edu).

A STUDY  
OF THE DIVIDE-DEWEY CONTACT OF  
THE BOULDER BATHOLITH

by  
FRANCIS M. YOUNG

A Thesis  
Submitted to the Department of Geology  
in partial fulfillment of the  
Requirements for the degree of  
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES  
BUTTE, MONTANA  
June, 1950

**MONTANA SCHOOL OF MINES LIBRARY**  
**BUTTE**



A STUDY  
OF THE DIVIDE-DEWEY CONTACT OF  
THE BOULDER BATHOLITH

by  
Francis M. Young

21990

A Thesis  
Submitted to the Department of Geology  
in partial fulfillment of the  
Requirements for the degree of  
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES  
BUTTE, MONTANA  
June, 1950

# TABLE OF CONTENTS

	Page
ABSTRACT . . . . .	1
INTRODUCTION . . . . .	3
PHYSIOGRAPHY . . . . .	7
GENERAL GEOLOGY . . . . .	9
Sedimentary Rocks . . . . .	9
Igneous Rocks . . . . .	9
Metamorphic Rocks . . . . .	10
Structure . . . . .	11
GEOLOGIC HISTORY . . . . .	13
CONTACT PHENOMENA . . . . .	15
Igneous Rocks . . . . .	15
Metamorphosed Sediments . . . . .	16
Inclusions . . . . .	16
General Observations . . . . .	18
Petrology and Chemistry . . . . .	20
Orientation . . . . .	25
CONCLUSIONS . . . . .	27
BIBLIOGRAPHY . . . . .	28



## LIST OF ILLUSTRATIONS

		Following Page
Plate I	Geologic Map . . . . .	In envelope
Plate II	Structure Map . . . . .	In envelope
Plate III	Table of Sedimentary Rocks . .	9
Plate IV	General views of topography . .	9
Plate V	Dike Rocks and a Hornblende "Segregation" . . . . .	16
Plate VI	Transition from Granodiorite to Inclusion . . . . .	22
Plate VII	Greenish sandstone Inclusion .	22
Plate VIII	Typical Inclusion . . . . .	22
Plate IX	Typical "swarms" of Inclusions Exposed in the Big Hole Canyon.	25

A STUDY OF THE DIVIDE-DEWEY CONTACT OF  
THE BOULDER BATHOLITH

by  
Francis M. Young

A B S T R A C T

The marginal relationships of the Boulder batholith to enclosing sedimentary rock between Divide and Dewey in southwestern Montana show striking effects of wall rock assimilation. Sedimentary rocks, from Devonian to Recent in age, were folded and faulted during the Laramide revolution, following which the batholith was intruded. The batholith is dated as Paleocene or early Eocene. The rocks of the batholith in this area are classified as ranging from quartz-granodiorite to granodiorite. Variation in mineral content causes a change in color tone from light to dark gray. Swarms of inclusions occur in the igneous rock near the contact.

Sediments that lie near to the contact (50 to 100 feet) are so highly altered that stratigraphic identification is virtually impossible unless the beds are traced from outside the contact. Petrographic and chemical studies show that the inclusions within the batholith are derived



from adjacent sedimentary rocks. Orientation of the inclusions appears to be a local phenomena, but lack of sufficient data prevents deciphering an over-all trend.

## I N T R O D U C T I O N

The marginal relations of the Boulder batholith and folded sedimentary rocks are unusually well displayed in road and railroad cuts between Divide and Dewey in southwestern Montana about 30 miles south of Butte. Between Divide Bridge and the small town of Dewey, one sees a fascinating series of dark inclusions surrounded by, or floating in, the so-called Butte "granite", a granodiorite in this area. Although the color of the granodiorite ranges from light to dark gray, the inclusions are almost always darker than the surrounding material. The few exceptions to these color relationships are the large green-colored masses that occasionally lie within the intrusive mass.

A closer inspection of this contact zone shows that many of the inclusions blend into the surrounding rock with vague and obscure contacts. Other inclusions have distinct lines of contact, of which several are surrounded by a halo of hornblende or other femic minerals.

Another feature of these inclusions is their well defined orientation. In some areas of the contact zone the inclusions appear to have marked linear properties and give a schlieren-like appearance. Other inclusions show more simple lineation and look like a series of disks stretched into an irregular line. This may be indicative



of the direction of magma movement. Also within the granodiorite, "swarms" of inclusions may lie next to an area that is completely free of inclusions.

The area may be reached by following U. S. Highway 91 southward from Butte to Divide. At Divide a paved road leaves Highway 91 and travels westward along Big Hole River. Between Divide and Divide Bridge, a distance of about 3 miles, the intrusive granite and metamorphosed

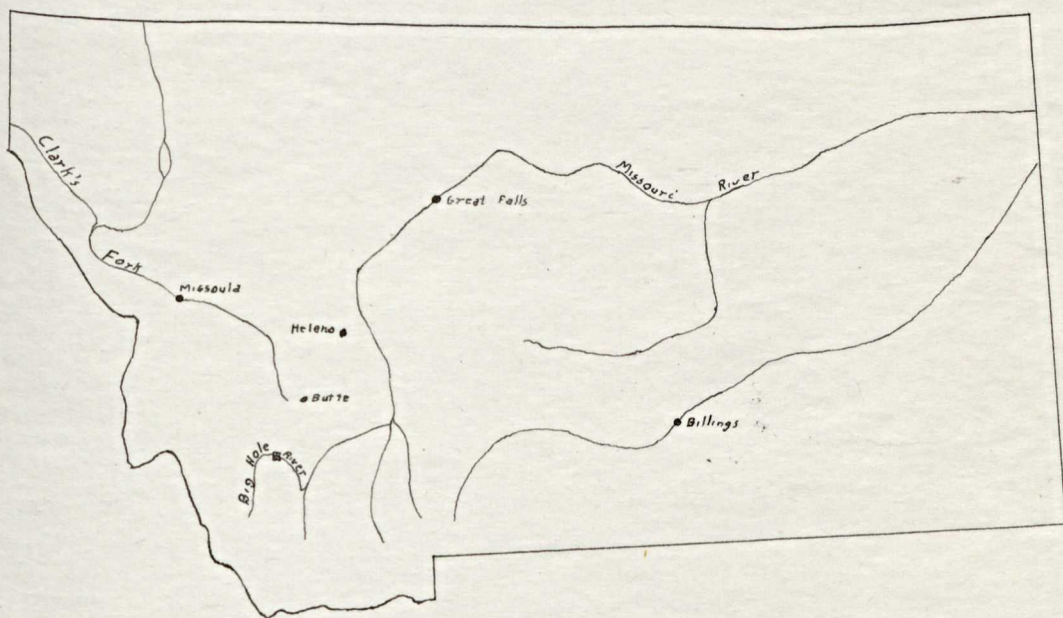


Figure 1. Index map of Montana showing the location of the area under consideration.

sediments lie to the north, while virtually unaltered sedimentary beds lie to the south. Shortly before reaching Divide Bridge, the sediments on both sides of the road are highly metamorphosed. A short distance



beyond the bridge and near the top of the old dam, the actual contact of the sediments and the batholith is poorly exposed. This contact is marked by a "contact breccia", and the brecciated appearance of the sedimentary fragments can be found as the contact is followed into the tree-covered mountains. From this contact westward to Dewey Flats, highway cuts have made excellent exposures of the granodiorite. The cuts along an abandoned narrow-gage railroad on the north side of the river also expose the contact phenomena.

A study of this area was undertaken during the summer of 1949 as part of the requirements for a bachelor of science degree in geological engineering at the Montana School of Mines. The purpose of the study was to attempt to discover the relationship of the inclusions in the batholith to the igneous mass itself. The writer also hoped that this study might aid in a broader understanding of the entire problem of the Boulder batholith. With these views in mind, many samples of the granite, the inclusions, and contacts between the inclusions and the granite were obtained, and a brunton compass survey of the flow structures was made.

Although this area had been previously studied in some detail by F. F. Grout and others, a point not recognized when the project was started, the present



investigation served to add some additional structural information and to raise the confidence of the writer in his ability to adequately interpret field observations.

Under the guidance and suggestions of Dr. Perry and Professor Robertson of the Department of Geology, the writer assembled the known facts of this area. From this point, new information gleaned in the field and in the study of thin sections was added. The report was then presented as a composite of the work accomplished in this area.

## P H Y S I O G R A P H Y

The road between Divide Bridge and Dewey Flats is cut into the rock of a deep gorge-like valley formed by Big Hole River. Abrupt cliffs, broken by V-shaped tributary valleys, rise from the valley bottoms to a height of several hundred feet. Above these cliffs, on the south side of the river, evergreen trees cover a rugged topography which was formed under the influence of the sedimentary and igneous rocks which to some extent controlled the stream pattern that had developed during Tertiary time. North of the river the topography above the sides of the canyon becomes gentle. The approaches to Mount Fleecer, north of the area under consideration, are long gentle slopes. Within the canyon the steep sides of the valley are unbroken except where small tributaries to the river have incised themselves to the valley floor. Most of these streams are intermittent.

The talus slopes below the bridge on the south side of the river are steep, and the slide rock, composed principally of hornfels, rises abruptly from the river bottom. On the north side of the river the talus slopes are more gentle, and the entire appearance of the mouth of the canyon gives the impression that the river is gradually forcing itself southward by lateral cutting.



Above Dewey Flats the valley widens, and except for a few narrow portions, this width is maintained until the river reaches Big Hole Basin 30 miles westward. This basin is a portion of an old Tertiary drainage system whose rivers flowed southward instead of in the northerly and easterly direction of the present drainage system (6, p. 3).

The evergreens in the area south of the river are mostly pine with some spruce and fir. Immediately north of the river the slopes are grass covered, the evergreens being absent except for scattered patches until higher elevations are reached. Along the river valley floor, and in small tributary valleys, willows and aspen form a heavy growth. A variety of plant life grows throughout the entire area. In high and relatively flat and dry areas, sagebrush grows as high as 6 feet. This sage is used by wild animals, particularly deer, for shelter from the penetrating winds that sweep the country.

The climate is relatively harsh, temperatures ranging from a summer maximum of 90° to 100° to a winter low of between minus 35° to 45°. Deep snow fills the valley and covers the mountains during the winter.



## GENERAL GEOLOGY

### Sedimentary Rocks

The sedimentary rocks of this immediate area are from Devonian to Recent in age. In the area covered by Plate I, the pre-Devonian sediments are absent either because they have not yet been exposed by erosion or because they have been removed by the igneous body. The usual sedimentary series of southwestern Montana is present, but because this study is not primarily concerned with sedimentary strata, the writer has summarized this information in the form of a table (see Plate III). The reader is referred to Puumala (7), Roe (8), and U. S. Geological Survey Bull. 780 (5) for more detailed descriptions of these sediments. Most of the information contained in Plate III was taken from these papers.

### Igneous Rocks

The igneous rocks of the area are essentially quartz-monzonite, granodiorite, and diorite of the Boulder batholith. Many dikes of aplite, pegmatite, and of basic rock are present. Puumala (7, p. 15) states that the igneous rocks in the immediate area are somewhat more dioritic than the rocks of the batholith proper. He also states that this may be due to assimilation of the nearby



# Column of Sedimentary Strata

Age	Formation	Description
Quaternary	Alluvium	Recent stream deposits, angular sand and rock fragments on terraces and rounded material in beds of streams
Tertiary	Glacial drift	Typical glacial drift, some striated boulders
	Lake beds	Unconsolidated, light-colored clay and sand, containing local conglomerates, exposed thickness 100 to 500 feet
Cretaceous	Colorado	Black fissile sh, greenish-gray ss, basal sh is brown with thin ls beds that contain altered pyrite, 1000 feet more or less
	Kootenai	"Salt and pepper" ss, maroon, greenish, and yellowish sandy sh, bluish-gray ls, 1500-1700 feet
Triassic	Thaynes	Gray ls, variagated shale and ss, less than 100 feet
	Woodside	Ss and sh, interbedded ls, 200 feet more or less
	Dinwoody	Ss, sh, ls, 300 feet more or less
Triassic-Jurassic	Undifferentiated	Sh, ss, and thin ls, metamorphosed to hornfels, 300 feet
Mesozoic	Undifferentiated	Sh, ss, and thin ls, metamorphosed to hornfels, 1730 feet
Permian	Phosphoria	Black phosphatic rock, and black chert, some thin ls beds, 300 feet.
Pennsylvanian	Quadrant	Hard, vitreous quartzite, 800 feet
Mississippian	Big Snowy Group	Thin-bedded, dark sh, interbedded ls, 300 feet
	Madison	Massive, light to blue-gray ls, 1300 to 2000 feet
Devonian	Threeforks	Green and black sh, argillaceous ls, 145 feet

Plate III. Table of sedimentary rocks of the Divide-Dewey area.





Fig. IV a. Looking north from old dam. The contact is hidden by talus near center of picture. Mesozoics undifferentiated at left.



Fig. IV b. Typical outcrop of granodiorite.



Fig. IV c. Looking south just above dam.

Plate IV. General views of the Big Hole Canyon.



sediments, but Grout (4) maintains that the dioritic nature is due to an early dioritic facies of the batholith.

Small patches of extrusive basalt and rhyolite are present on the outskirts of the area. Their locations are shown on Plate I. Because these rock types are not found in the immediate area under consideration, the reader is referred to Puumala for their description. Puumala also describes the various types of dikes. The writer noted several between Divide Bridge and Dewey, and this type of material will be described later in this report.

#### Metamorphic Rocks

The metamorphic rocks of this area may be broadly classified into hornfels and marbles. The hornfels are particularly well developed near Divide Bridge, and the Mesozoic sediments present have been so intensely altered that if it were not for the presence of bedding planes, it would be difficult to distinguish the metamorphic material from fine-grained igneous rocks.

The inclusions themselves, which are believed by Grout to be derived from the adjacent sediments, are so altered that they have the appearance of igneous material, dioritic or gabbroic in character. The principal megascopic difference between the inclusions and the surrounding



granodiorite is the darker color and finer texture of the inclusions.

### Structure

The entire sedimentary series of this area was tightly folded and faulted during the Laramide revolution. Grout (3, p. 879) quotes Perry as stating "The Boulder batholith is mainly in a synclinal area..." While this holds for the overall picture, small synclines and anticlines are superimposed on the major structure. North of Big Hole canyon an anticline plunges northward; south, a series of anticlines and synclines follow one upon the other; and to the west, a tight syncline is to be found just west of Dewey (5, 7, 8). The beds to the west and south have been folded tighter than those to the north.

Plate II shows how the batholith cuts directly across the folded sedimentary strata, suggesting that the magma inserted itself after the completion of the folding. The roof pendant north of the river contains sedimentary formations that align themselves nicely with the formations south of the river. The truncation of the sedimentary strata indicates that the batholith was intruded after the Laramide orogeny.



The structure present today is the result of the folding and faulting of the virtually horizontal Paleozoic and Mesozoic strata, the emplacement of the intrusive, and later features formed during Cenozoic time. These later features were essentially block-faulting which developed intermontane lakes by damming the south-flowing streams. The last structural features formed were developed during the time in which the lakes were drained, resulting in the formation of the Recent erosion pattern which is now present.



## G E O L O G I C     H I S T O R Y

Paleozoic and Mesozoic sediments present in this area were deposited in a relatively horizontal position. Local and regional unconformities are present. These beds were involved in the Laramide orogeny that created the first Rocky Mountains.

This paper is concerned with the history that took place after the folding and faulting of the Laramide orogeny, for the batholith was not intruded until this early revolution had died out.

The following brief summary of time relations is adapted from Billingsley (2, p. 35), and others:

1. Middle Cretaceous--Main Rocky Mountain folding, and formation of the large earth folds in northwesterly direction.
2. Middle-Upper Cretaceous--Extensive erosion.
3. Upper Cretaceous--Andesite eruption.
4. Upper Cretaceous (?)--Local intense erosion.
5. Upper Cretaceous (?)--Thrust faulting and folding in northwesterly direction, with local intensification of folding.
6. Paleocene or early Eocene--Intrusion of Boulder batholith.
7. Eocene--Extensive erosion, developing peneplain and well-adjusted river system. Early rhyolite.
8. Oligocene--Normal north-south faulting and lake development. Erosion of peneplain.
9. Miocene--Further accumulation of river and lake deposits. Later rhyolite and dacite.



10. Pliocene-Pleistocene--Uplift and erosion (6).
11. Pleistocene--Glaciation, forming Cerro till (7).
12. Recent--Formation of present erosion pattern.



## C O N T A C T     P H E N O M E N A

### Igneous Rocks

The normal intrusive rock of the Boulder batholith is a quartz monzonite. Grout (4) and Billingsley (2) both mention an early dioritic facies at the north and south ends of the batholith, but the writer did not see any indication of a "basic border zone" in the area under consideration.

Microscopically, the granite is classified as ranging from a quartz-granodiorite to a granodiorite (Johannsen classification). Both the road and railroad cuts show color variations of the granodiorite, and the writer believes that the changes, from light to dark gray, are caused largely by the varying quartz content. An increase in quartz is accompanied by a drop in both feldspar and femic minerals.

The material collected for study was inadequate for a determination of the relationships of the change in color to either the contact or the inclusions. Field work did not give any indication of these relations. Further investigation of this phase of the contact is needed.

The dikes cut through both the igneous-looking inclusions and the igneous rock. The material in



different dikes ranges from virtually pure feldspar to basic minerals. The feldspar dikes frequently have large crystals of quartz, feldspar, and biotite, showing a pegmatitic nature. A short distance above the dam, one pegmatite dike changes from almost pure, uneven-grained feldspar to definite crystals of quartz, orthoclase, and a zeolite. The basic dikes, lamprophyres, are generally thick, but are much less numerous than the acidic dikes. The writer collected samples from only one, and has classified the rock as a melagabbro.

#### Metamorphosed Sediments

The sediments that border the contact near Big Hole canyon are largely shale with some thin interbedded sandstone and limestone. Massive limestone and thick sandstone are present farther from the canyon. The presence of phosphatic sediments is suspected, but no definite information as to the actual presence of such beds at the contact can be gained by megascopic examination.

The shales have been metamorphosed to fine-grained hornfels, so that unless they are traced from some distance outside of the contact they cannot be identified. The metamorphosed sediments just north of the bridge cannot be separated into definite stratigraphic units. This is also true of the beds north of the area that





Fig. V a. Feldspar dike rock.



Fig. V b. Pegmatite, showing orthoclase and quartz.



Fig. V. c. Basic rock, a melagabbro, from lamprophyre dike.



Fig. V d. Concentration of hornblende in granodiorite.

Plate V. Dike rocks and a hornblende "segregation".



rest upon the granite. Puumala (7, pp. 21-23) studied these metamorphosed sediments in thin section, and states that little information was found that would assist in determining from what stratigraphic unit the hornfels were derived.

The limestone has been altered to marble. This metamorphism has a greater lateral tendency than the metamorphism of the shales, and is probably due to the greater energy requirement to recrystallize the shale beds. The effects of metamorphism for both types of rock is usually not intense at a horizontal distance of 1000 feet from the contact. However, the beds on the south side of the river and just below the bridge over 1000 feet from the contact are intensely altered, and the writer believes that the granite underlies these beds at slight depth.

### Inclusions

Much of the information for the following study of the inclusions is taken from the work of Grout (3, 4), but observations of other writers and the present writer are drawn upon. The immediate area of all observations is along the Big Hole river between Divide Bridge and Dewey. This area holds the excellent exposures of the contact zone that have been mentioned previously.



### General Observations:

The inclusions are of a darker color and finer grain than the host rock. They are abundant throughout the region, and become distinct in the weathered outcrops as they do not disintegrate as rapidly as the granodiorite. The contact itself can be recognized by the brecciated appearance of the inclusions within a foot or two of the actual contact. The brecciated zone can be followed into the timber on the north side of the river, but is obscured on the south side by talus-covered slopes.

Beyond the zone of brecciation, the inclusions take on their characteristic appearance. They appear as circular or elongated disks, ranging in size from a few inches to one foot or more. While most of the inclusions of any one outcrop are usually about the same color and texture, there are many places where they range from a light gray to almost black within a distance of a few feet. There is no "zoning" of this color effect, for the different colors are mixed.

Some of the inclusions have distinct boundaries while others seem to blend into the granite. Many of the inclusions have reaction rims of augite or hornblende, and commonly the hornblende crystals are arranged almost perpendicular to the boundary of the inclusions.

The indistinct boundaries of the inclusions and of the host rock are usually more noticeable where parallelism



of fragments is more obvious. However, in several places, particularly where the inclusions become numerous, the boundaries of the inclusions are distinct even with the presence of notable parallel arrangements. Streaks of dark material can be seen cutting through the granodiorite and around the inclusions. The writer believes that the streaks are the remainders of small inclusions digested or nearly digested by the magma. It is possible that magma movement at or near the contact was able to assist in assimilating wall rock and the fragments of wall rock which may have floated out into the magma.

Megascopically, the mineral determinations of the inclusions is hindered by their fine-grained character. The hand lens frequently brings out grains of quartz, plagioclase, hornblende, and biotite, but quite commonly the grain size is so small that the minerals cannot be identified. The grains range in size from 0.025 mm to almost 4 mm, and it seems that their size increases in general from the contact towards the center of the igneous body.

This change in grain size is not constant, for frequently an inclusion with a hornfels texture will be near one with a porphyritic texture. The writer feels that perhaps the inclusions farther within the igneous body had a longer time to digest and to recrystallize



minerals than those close to the contact. The original grain size of the sedimentary rocks would also influence the present size of the mineral grains.

Besides the inclusions with igneous textures, which are the most abundant, some inclusions of limestone 1 to 2 feet in length are present. These frequently have rims of augite (no hornblende was observed) which are less than one inch thick.

Another type of inclusion that is present consists of large, green-colored masses. These have a thickness of 2 to 4 feet and a length of from 6 to 12 feet. One of these greenish bodies was observed to be not less than 15 feet thick. The extremely small grain size prevents any megascopic determinations, but a thin section of this material showed it to be derived from a sandstone, or at least to have the characteristic appearance of a sandstone. A small percentage of pyroxene and chloritic material gives the rock its characteristic green color. (See Plate 6).

#### Petrology and Chemistry

By following a shale bed towards the contact, one can observe the alteration of the shale to hornfels within a distance of 1000 feet. At this distance from the contact the shales are only slightly altered, but within 100 feet, the intensity of the alteration can readily be observed.



Just inside the contact the breccia zone previously mentioned is found. In this zone the inclusions are highly angular, although otherwise they resemble the hornfels in nearly every detail; however, as one moves into the granodiorite, the inclusions become more rounded and more igneous in appearance. The inclusions within the granodiorite have a mineral suite similar to that of the matrix, but there is a difference in the proportions of the minerals. The following comparison of the host rock and the inclusions is taken from one of the writer's slides (see Plate 7).

Mineral	Granodiorite	Inclusion
Quartz	40%	10%
Plagioclase (Andesine)	35	45
Orthoclase	5	trace
Hornblende	5	35
Biotite and Chlorite	15	5
Magnetite	trace	5 (minus)
Sphene	trace	trace

This comparison is given to illustrate the similar mineral suite of the inclusions and the host; but as the host rock, as well as the inclusions, differs somewhat in composition from place to place, no one slide will show the same percentages as another slide. For example, the

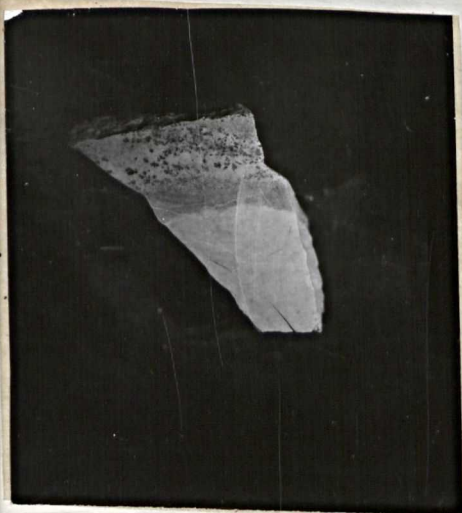


quartz content of the granodiorite ranges from 35 to nearly 45 per cent. In some areas, hornblende dominates over biotite, and in others, large books of biotite are almost the only femic mineral present.

One of the samples of a contact (Plate 6) shows an intermediate zone between the inclusion and the magma, each facies being separated by a distinct boundary. A thin section of this rock shows two changes as the observer moves from inside the inclusion outward. The first is a distinct change in grain size, the grains almost doubling from the inclusion (0.025 mm) to the intermediate zone (0.050 mm), and again doubling when the granodiorite is entered. These measurements were taken for quartz. The granodiorite contained large crystals of hornblende, slightly over 1 mm, besides the smaller quartz grains.

The second change was in the mineral content. The inclusion itself contained, besides quartz, very fine-grained chlorite. Hornblende, unnoticeable in the inclusion, became an important constituent in the intermediate zone, and still more important in the host rock. In the granodiorite, the hornblende crystals surrounded the smaller quartz grains, giving the impression that the femic mineral grew around the quartz while maintaining its own crystal structure. A picture of this crystal is shown on plate 6.





Granodiorite  
Transition  
Inclusion



Fig. VI b. Inclusion

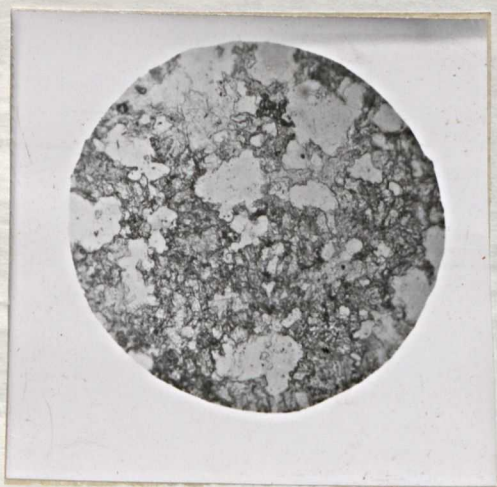


Fig. VI c. Transition zone

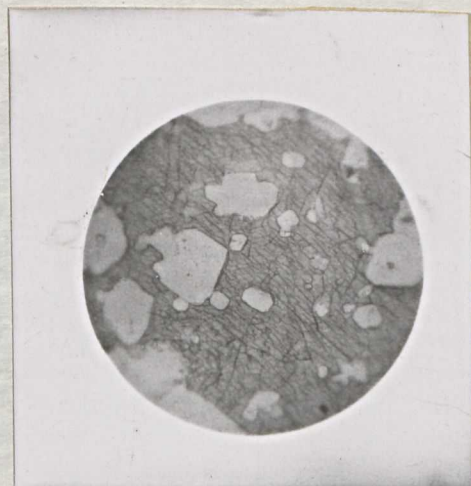


Fig. VI d. Granodiorite,  
showing horn-  
blende crystal  
surrounding quartz.

Plate VI. Fig. a shows a transition zone between an inclusion and the granodiorite. The various facies are marked on the side of the figure. The photomicrographs are of the portion of the rock indicated (X20)





Fig. VII a. Outcrop of large, green, sandstone inclusion.



Fig. VII b. Specimen of the above outcrop

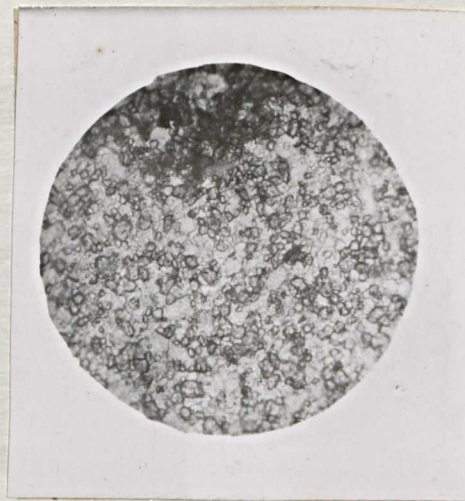


Fig. VII c. Microphotograph showing small pyroxene grains. (X25)

Plate VII. Outcrop, specimen, and microphotograph of greenish colored sandstone inclusion.





Fig. VII a. Typical contact between granodiorite (light) and inclusion (dark)



Fig. VIII b. Photomicrograph of granodiorite.



Fig. VIII c. Photomicrograph of inclusion.

Plate VIII. Typical inclusion and photomicrograph of inclusion and granodiorite. Note zoning of plagioclase of granodiorite and the smaller grain size of the inclusion.



Grout (3, 4) gives detailed descriptions of the igneous-looking inclusions, tracing them from outside the brecciated zone to over 300 feet within the magma. The following excerpt from his paper (4, p. 1561) describes the changes from the hornfels to the inclusions:

"The shale hornfels outside the brecciated contact zone has a grain size about 0.04 mm, and contains about 40 per cent quartz, 25 per cent feldspar, 30 per cent biotite and other mafic minerals, and a small percentage of several minor accessories. The texture is granoblastic, 'sugary', and analogous to shale hornfels elsewhere.

"The hornfels of the contact breccia shows a grain size about 0.07 mm and contains 40 per cent quartz, 50 per cent biotite, chlorite, and other mafic minerals, 6 per cent muscovite and sericite, and 2 per cent magnetite, with accessory pyrite, apatite, and leucozene.

"An inclusion with exactly the appearance of the hornfels contact rock was found six inches inside the contact in the intrusive. It has a grain size about 0.17 mm and contains 6 per cent quartz, 40 per cent labradorite, 10 per cent biotite, 35 per cent amphibole, 5 per cent magnetite, and a little pyrite. The amphibole seems to have formed at the expense of the biotite and quartz.

"An inclusion in the great swarm along the banks of the Big Hole River about 100 yards from the contact, had a porphyritic texture with "phenocrysts", 1 to 3 mm long, in a matrix that had an average grain of 0.3 mm. This contained 2 per cent quartz, 60 per cent labradorite, 20 per cent hornblende, 15 per cent biotite, and 3 per cent magnetite."

The present writer questions the accuracy of an inclusion "six inches" from the contact because there is a progressive increase in the abundance of inclusions



from magma to host rock, thus making it difficult to determine the inclusions from the actual sediments within a distance of at least 3 feet. However, for the purposes of this paper, Grout's measurement will be assumed to be reasonably accurate.

This petrographic series shows that the rocks near the contact are somewhat intermediate between the shale hornfels and the inclusions. This indicated to Grout that the inclusions are of sedimentary origin. The writer is in agreement, not only because of the information given by Grout, but also because of the general appearance of the inclusions in the field and through the study of thin sections, particularly the one described on page 22 of this paper.

Table 1 and Table 2 are also taken from Grout. Table 1 shows some trends in alkalies and iron oxides of a series from the shale to the inclusions. Table 2 gives a complete analysis of the oxides of these materials. These tables show a definite trend towards an igneous material as the shale is followed into the contact. The inclusions consistently become more basic as can be seen by the decrease in silica and increase in calcium, and they contain more lime, magnesia, iron oxide, titania, and less potash and silica than the shale.

Grout states that this is exactly the changes that are known to occur elsewhere in a series from slate to



Table 1.

Graduation in alkalies and iron oxide from  
Cretaceous shale to inclusions in and near the  
Boulder batholith (adapted from Grout, 1937).

	Total iron as Fe <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	K <sub>2</sub> O	Na <sub>2</sub> O plus K <sub>2</sub> O
1. Shale 100 yds outside granite	5.62	.51	2.36	2.87
2. Shale, 1-100 yds, composite	4.66	1.28	2.36	3.64
3. Shale about 20 yds outside of contact	4.58	1.77	2.69	4.46
4. Hornfels breccia at contact (1931)	6.01	1.71	1.60	3.31
5. Hornfels breccia at contact (1932)	4.34	1.41	1.74	3.15
- - - - - contact - - - - -				
6. Hornfels inclusion 6 inches inside contact	8.87	.94	1.10	2.04
7. Sedimentary hornfels inclusion near contact	3.10	.61	.70	1.31
8. Inclusion 100 yds inside granite	9.46	3.32	1.53	4.85
9. Composite of inclusions 1 to 500 yds in from contact	10.23	2.82	1.55	4.37
10. Typical inclusion far in granite	10.31	3.76	1.45	5.21



Table 2.

Analysis of shale, hornfels, and inclusions in granite of the Boulder batholith along the Big Hole River, east of Dewey, Montana (adapted from Grout, 1937).

Oxide	Shale	Shale hornfels	Hornfels breccia	Hornfels inclusion	Dark Inclusion	Dark Inclusion
	1*	3	4	6	8	10
SiO <sub>2</sub>	65.53	69.73	67.33	55.15	51.97	49.18
Al <sub>2</sub> O <sub>3</sub>	16.82	15.95	14.57	17.95	19.38	20.24
Fe <sub>2</sub> O <sub>3</sub>	.38	.49	.74	.37	3.71	3.72
FeO	4.72	3.68	4.74	7.65	5.18	5.93
MgO	2.44	1.76	2.67	5.71	3.45	4.62
CaO	4.00	1.61	2.79	8.16	8.22	8.69
Na <sub>2</sub> O	.51	1.77	1.71	.94	3.32	3.76
K <sub>2</sub> O	2.36	2.69	1.60	1.10	1.53	1.45
H <sub>2</sub> O	1.32	.99	1.96	1.01	.73	.72
H <sub>2</sub> O	.25	.26	.22	.17	.11	.05
CO <sub>2</sub>	.18	.05	.24	.11	.16	----
TiO <sub>2</sub>	.71	.61	.63	.96	1.29	.74
ZrO <sub>2</sub>	----	.02	.01	----	none	----
P <sub>2</sub> O <sub>5</sub>	.24	.24	.27	.24	.31	.44
S	.06	.05	.32	----	.03	----
MnO	.10	.06	.04	.24	.16	.17
BaO	.07	.11	.04	----	.05	----
Cl	----	----	----	----	.02	----

\* The numbers at the head of each column refer to the numbered samples of Table 1.



included hornfels. This might indicate a digestion of the hornfels inclusions, and the writer can see no criteria that would indicate that this had not taken place.

### Orientation

The orientations of the inclusions as shown by Grout (3), and as observed by the writer along the river, do not appear to fit into a well-defined pattern for the entire area, although locally the orientation is parallel. Grout's map (3) from which the principal foliations shown on Plate II were taken, shows a concentric arrangement of orientations over the area as a whole. But there appears to be several local irregularities contrary to the concentric pattern. These irregularities, which cannot be neglected, destroy the symmetry postulated by Grout. If many more determinations were plotted throughout the area, a more definite pattern might show itself. Time and weather conditions did not permit the writer to obtain such additional determinations.

From the information available, it would seem that local arrangement, or orientation, of the inclusions was affected more or less independently of adjacent areas. It is possible that the irregularities in orientation are related to the roof contact rather than to the wall contact of the batholith. The writer believes that the roof of the batholith was not a great deal higher than the roof





Plate IX. Typical "swarms" of inclusions exposed in the Big Hole Canyon.



pendant shown in Plate II. The pendant is approximately 1000 to 1500 feet above the floor of the canyon where the readings were made.



## C O N C L U S I O N S

The slightly more dioritic nature of the Boulder batholith in this area as compared to the typical material of the batholith proper is caused by the effect of the sedimentary beds that lie adjacent to the contact. Their assimilation by the magma undoubtedly altered the composition of the invading material.

The age of the batholith is post-Laramide, being either Paleocene or early Eocene.

The igneous rock of this area ranges from a quartz-granodiorite to a granodiorite. Change in quartz content accounts for color changes from light to dark gray of the igneous rock in this area.

The inclusions of the granodiorite are derived from the sediments. The pieces of sedimentary material that drifted out into the unconsolidated magma were digested until their original character has become obscured. Their sedimentary origin can be determined from field relations, chemical analysis, and petrographic study. The writer does not question their sedimentary origin.

The parallel orientation appears to be a local phenomena, but final observations regarding this point should be withheld until more detailed mapping of the parallelism of the inclusions is made.



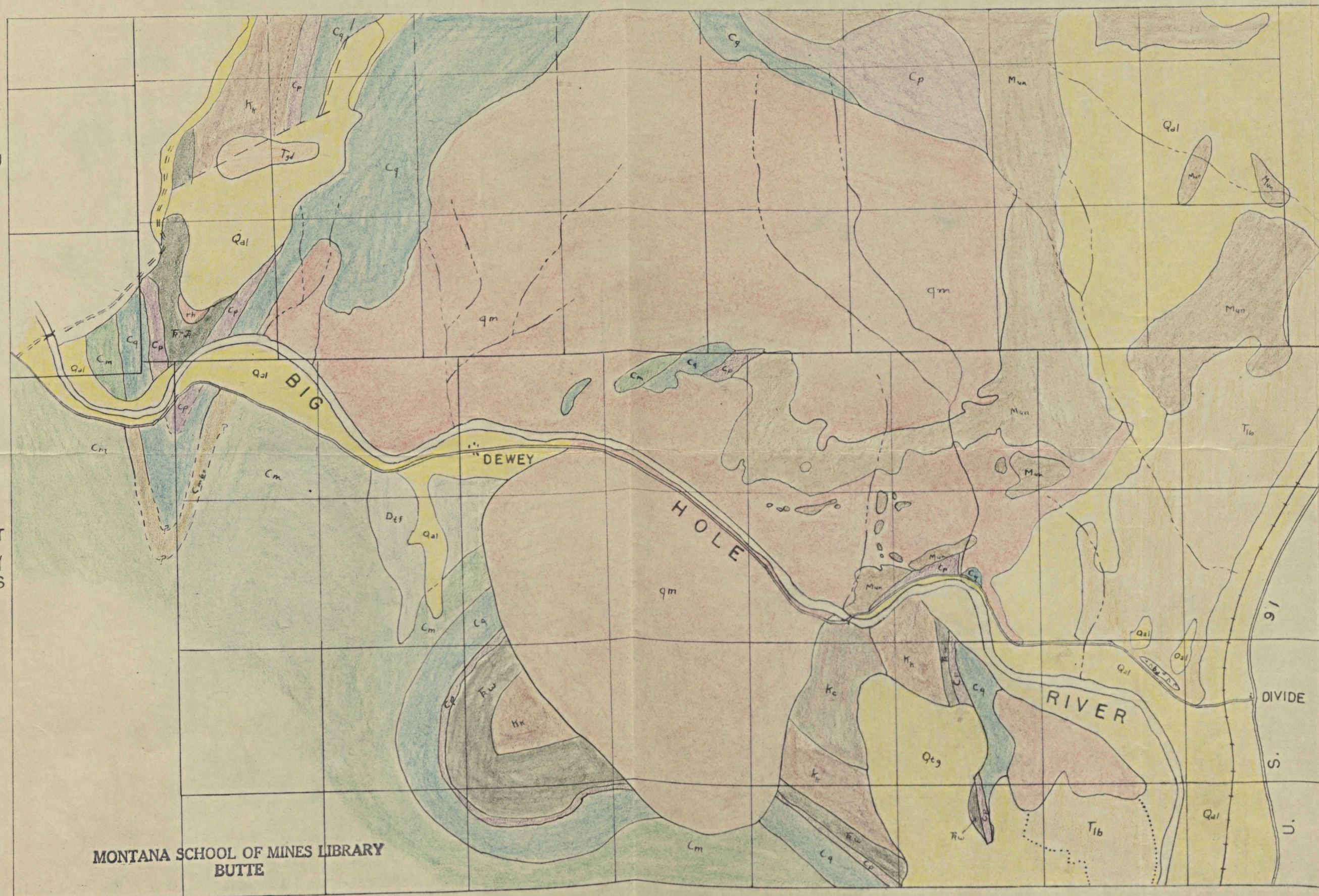
## B I B L I O G R A P H Y

1. Atwood, W. W., and W. W. Atwood, Jr., "Opening of the Pleistocene in the Rocky Mountains of the United States", Jour. of Geol., vol. 46, 1938, pp. 239-247
2. Billingsley, Paul, "The Boulder Batholith of Montana", A. I. M. E. Bull 97, 1915.
3. Grout, F. F., "Internal Structures in the Boulder Batholith", Geol. Soc. Am., Bull., vol. 45, pt. 2, 1934, pp. 877-896.
4. Grout, F. F., "Criteria of Origin of Inclusions in Plutonic Rocks", Geol. Soc. Am. Bull., vol 48, pt. 2, 1937, 1521-1572.
5. Loughlin, G. F., and G. R. Mansfield, "The Melrose Phosphate Field, Montana", U. S. Geol. Surv., Bull. 780, 1925.
6. Perry, E. S., "Physiography and Ground Water Supply in the Big Hole Basin, Montana", Memoir 12, State of Montana Bureau of Mines, 1934.
7. Puumala, P. P., Igneous Activity in the Mount Fleecer Area, Thesis, Montana School of Mines, 1948.
8. Roe, J. T., Geology of the Mount Fleecer Area, Thesis, Montana School of Mines, 1948.
9. Sherwin, Clifford G., Basic Inclusions in the Granitic Rocks of the Boulder Batholith, Thesis, Montana School of Mines, 1941.
10. Winchell, A. N., "Mining Districts of the Dillon Quadrangle, Montana, and Adjacent areas", U. S. Geol. Surv., Bull. 574, 1914.



T1N

T1S



# GEOLOGICAL MAP OF DEWEY-DIVIDE AREA MONTANA

AFTER  
PUUMALA & ROE, 1947  
&  
PLATE I, U. S. G. S. BULL. 780  
SCALE: 1 1/2" = 1 MILE

## EXPLANATION

### SEDIMENTARY ROCKS

- |       |                  |
|-------|------------------|
| Qal   | ALLUVIUM         |
| Tgd   | GLACIAL DRIFT    |
| Tlb   | LAKE BEDS        |
| Kc    | COLORADO         |
| Kk    | KOOTENAI         |
| Fw    | WOODSIDE         |
| Tr-Jr | TR-JR UNDIFF     |
| Mun   | MESOZOICS UNDIFF |
| Cp    | PHOSPHORIA       |
| Cq    | QUADRANT         |
| Cbs   | BIG SNOWY        |
| Cm    | MADISON          |
| Dsf   | THREE FORKS      |

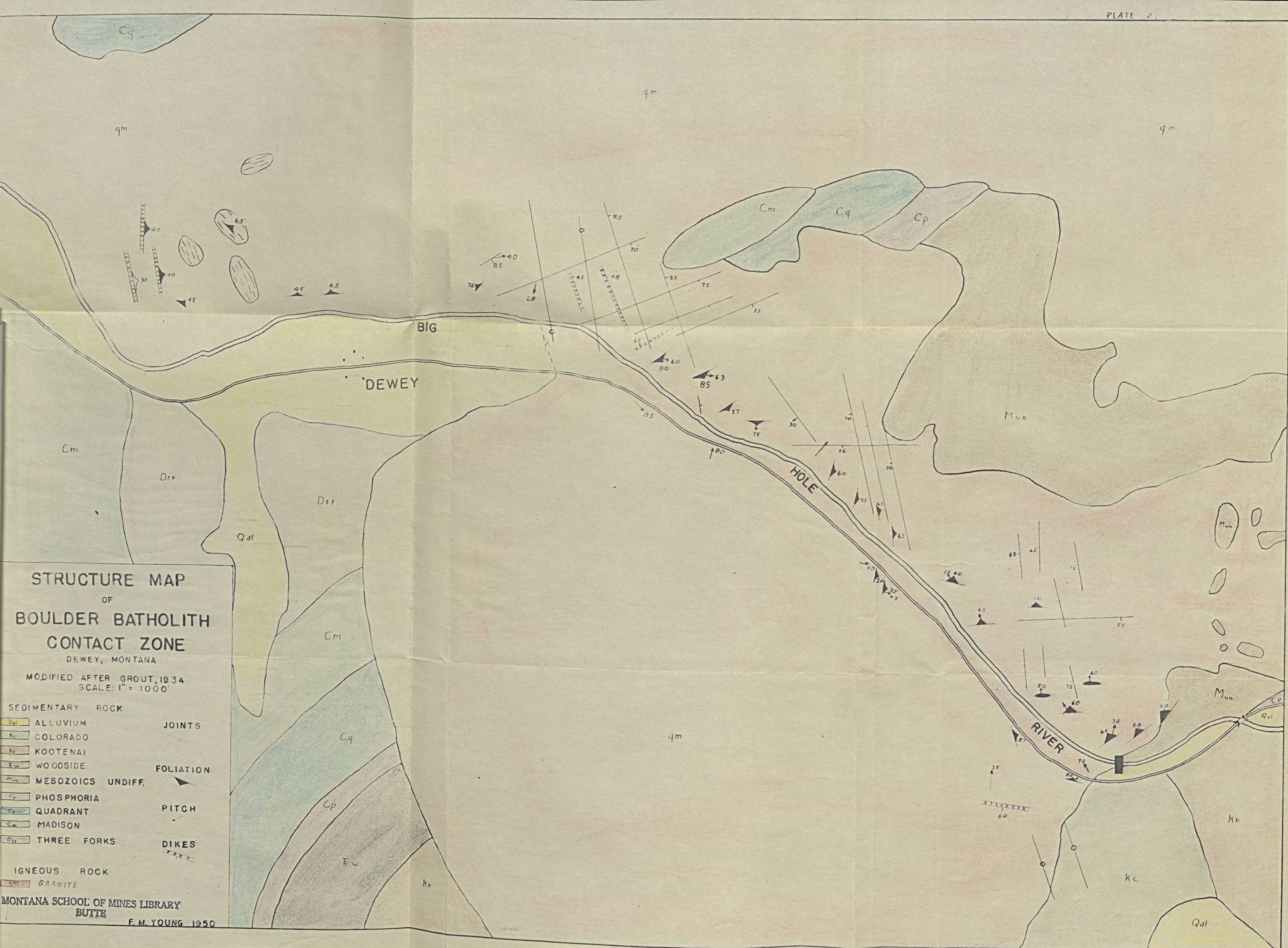
### IGNEOUS ROCK

- |    |          |
|----|----------|
| rh | RHYOLITE |
| ba | BASALT   |
| gm | GRANITE  |

MONTANA SCHOOL OF MINES LIBRARY  
BUTTE

MONTANA SCHOOL OF MINES LIBRARY  
BUTTE





STRUCTURE MAP  
OF  
BOULDER BATHOLITH  
CONTACT ZONE  
DEWEY, MONTANA

MODIFIED AFTER GROUT, 1934  
SCALE: 1" = 1000'

- SEDIMENTARY ROCK
- Qal ALLUVIUM
  - Kc COLORADO
  - Kh KOOTENAI
  - Wv WOODSIDE
  - Mun MESOZOICS UNDIFF.
  - Cp PHOSPHORIA
  - Cq QUADRANT
  - Cm MADISON
  - Dtf THREE FORKS
- IGNEOUS ROCK
- qm GRANITE
- JOINTS
- FOLIATION
- PITCH
- DIKES
- MONTANA SCHOOL OF MINES LIBRARY  
BUTTE  
F.M. YOUNG 1950